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SUBJECT Comments and Evaluation on Strength of Metals in Steam Boilers and Turbines

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Title

I. A. Oding: <u>Basis of the Strength of Metals in Steam Boilers, Turbines and Turbine Generators.</u> Moscow 1949. 560 pp.

A comprehensive book on conventional steam power plants. (Gas turbines, mercury boilers and nuclear-powered turbines are not considered.)

a. Almost exactly half the book is taken up by the first seven chapters, which cover the properties of metals in general with specific emphasis on steel: static and dynamic strength; toughness; plastic deformation and recrystallization; effect of elevated temperatures; residual stresses; corrosion and erosion.

b. The eight chapters in the second half of the book deal with individual parts of steam power plants: boilers; pipes, turbines, castings; bearings; turbine-generator rotors; stators; and various other less important parts. In each case, Oding discusses service requirements, materials used, inspection and acceptance tests, and failures.

Oding states that steam-turbine technology in the USSR is fully comparable with that in the US, Great Britain and other industrial countries. His book indicates, however, that in 1949 the Soviets were slightly behind the US, although by no more than perhaps four or five years.

a. According to Oding, the standard types of steam boilers made in the USSR (presumably in 1949) had a steam pressure of 100 at. and a steam temperature of 510 C. Boilers were then being designed for 170 at. and 560 C. In the US, a steam temperature of 510 C was exceeded by central-station boilers constructed in 1945; and 560 C, about 1947. Of all the orders for public-utility steam turbines received by General Electric Company between 1 May 1947 and 30 April 1950, for units of 10,000 kw and larger, 50% was for operation at 540/565 C. Moreover, a 145,000-kw turbine-generator unit installed in 1952 by the Public Service Electric and Gas Company in New Jersey is designed for an initial steam temperature of [illegible] the US about 1942, and 170 at., about 1950.

T. S. Fuller: Solving Problems in Materials. ASTM Bulletin no. 185 (1952) pp 51/62.

J. B. Romer and H. D. Newell: The Creep and Stress-Rupture Testing of Steam-Boiler Materials. TASME 74 (1952) pp 157/172; disc 172/174.

b. Oding points with pride to 100,000-kw and 3,000-rpm units. Although the production of such units is called "normal" in the preface, the text - probably written at a somewhat earlier date - does not give full details on them and treats them as a rather special item. According to Mochel, the level of 100,000 kw and 3,600 rpm was reached in the US about 1946, and exceeded in 1947. Furthermore, he stated 250,000-kw units had already been ordered and were in the design stage.

N. L. Mochel: Man, Metals, and Power. Proc ASTM 52 (1952) pp 690/731.

3. As far as materials are concerned, most are more or less the same as those used in other countries for units operating under comparable conditions. In general, however, fewer grades, more carbon steels, and fewer highly alloyed steels are listed than would come into consideration in the US. The first of these items probably reflects the greater possibilities of standardization in a socialized economy; the latter two may be due in part to lower temperatures and lower working stresses.

a. The Soviets indicate that alloy steel must be used at temperatures over about 420 C. This is in agreement with general practice elsewhere.

b. Because of the lower temperatures involved, the Soviets have apparently not yet had to give serious and detailed consideration to the grades that would be necessary if higher temperatures were adopted.

(1) Table 4-8 includes some "superalloys". Mention is made of minor uses of EI-60 and EI-257, which correspond roughly to the "TPA" type used in the US mainly for aircraft exhaust valves. There is no indication, however, as to whether the other alloys are being considered for steam power plants.

(a) EI-424 is a high-carbon modification of Timken alloy, or 16-25-6, which has been widely used in the US for gas-turbine disks. As against the 0.4% C shown, Timken specify 0.12% C maximum for good forging and welding qualities. The fact that this grade has a Soviet symbol would tend to indicate it had found some use in the USSR.

M. Fleischmann: 16-25-6 Alloy For Gas Turbines. Iron Age 157 (1946) no. 3, pp 44/53; no. 4, pp 50/60.

(b) The "Tinidur" was originally a German grade used to some extent in gas turbines.

(c) The "Westinghouse" seems to be a low-titanium version of K-42B, which is also mentioned on page 137. Since this grade depends on titanium for precipitation hardening, the lower titanium version would be expected to give inferior properties as compared to the standard material with about 2.6% Ti.

(d) The molybdenum content in "Vitallium" is significantly lower than the amounts specified in the US.

(e) Oding also seems to be unaware of the fact that most of the grades relying on titanium for precipitation hardening are precipitation hardened before they are put into service.

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2) There is no indication as to what tubing grades would be necessary for higher temperatures. In the US a program to evaluate commercially available alloys for suitability as to superheater and reheater tubing for metal temperatures as high as 730 C is sponsored by the ASME Special Research Committee on High-Temperature Steam Generation. A number of papers have already been published on various phases of this program, which has been under way for several years.

3) Oding does not take up the serious question as to whether austenitic steels are necessary for 595 C steam.

F. A. Ritchings and S. Crocker: Design of Steam Piping and Valves for 1100 F. ASME preprint no. 53-SA-37 (1953).

4) Oding does not consider the subject of steam-turbine rotors with better properties at higher temperatures, whereas this question was already under investigation in the US in 1949. The "recent" use of 0.6/0.7% Mo in disks mentioned by Oding on page 333 appears to have been based merely on greater ease of obtaining uniform properties in larger sections, and not on improvement of elevated-temperature properties.

US Naval Engineering Experiment Station: Materials for Steam Turbine Rotors. EESC-1689-D (5 May 49).

In the case of large forgings, fewer and less highly alloyed steels are specified in general, and the final hardnesses (strengths) are appreciably lower than would be the rule here.

(1) ASTM A 293-52T specification for turbine rotors and shafts gives six classes of alloy steel, vs only two for the Soviets. Moreover, the minimum yield strength (0.02% offset) for the highest category is about 67 kg/mm^2 - roughly twice the yield point specified for the highest category listed by Oding. The picture is about the same when ASTM A 292-52T for turbine generator rotors and shafts is compared with the Soviet requirements. There is a lesser, but still sizeable, strength differential in favor of the US turbine bucket wheels, as shown by a comparison of ASTM A 294-52T and the Soviet requirements.

(2) Despite the emphasis Oding places on residual stresses, liquid quenching is used for larger forgings than would be acceptable here, where its use is strictly limited by most specifications. Liquid quenching, however, is widely applied in Great Britain and Germany, even for the largest sizes of forgings.

S. Ammareller and P. Grun: Stahle fur grossere Schmiedestucke. Stahl und Eisen 72 (1952) pp 653/662.

H. H. Burton: Forgeage, Traitement Thermique et Controle Metallurgique d'un Rotor en Acier Allie. Comtes Rendus des Hournees de la Grosse Forge (May 1948).

H. H. Burton: Improved Manufacture of Large Alloy Steel Forgings. Metal Progress 63 (1953) no. 1, pp 125/129.

(3) The Soviets appear to prefer acid-open-hearth steel for large forgings, as do many in other countries, although it is now conceded by most that properly made basic-open-hearth steel gives equivalent properties.

The turbine-blade materials are fairly well in line with those used elsewhere; although Oding does not show the molybdenum modification of the 12% Cr steel that is used here for drop-forged blades (class c of MIL-S-861 of 15 Mar 50). It is interesting that there is no mention of low-alloy blades, such as the German grades 20 CrMo 44 and 24 CrMoV 55, which are said to give good performances under certain conditions.

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H. Niermeyer: Werkstoff- und Gestaltungsprobleme bei Dampf- und Gasturbinen. Archiv fur Metallkunde 2 (1948) pp 145/154.

The brazing procedures given by Oding appear to be less up-to-date than those used in other countries.

T. H. Gray: Furnace Brazing 12 per cent Chromium Low Carbon Steel. Steel 121 (1947) no. 3, pp 104/106, 124, 127/128.

J. H. G. Monypenny: Stainless Iron and Steel. Nol 1 - Stainless Steels in Industry. London (1951).

e. The differences in composition between the cast steel grades given by Oding, and those in ASTM A 356-52T, are again probably the result of lower steam temperatures in the USSR. Some of the Soviet castings are merely annealed, whereas the ASTM specification requires a normalize and temper. It is difficult to understand the emphasis Oding places on obtaining a fine grain size in these steels since the elevated-temperature properties are better with a coarse grain size. In the US some producers desire a coarse grain structure, free from ferrite, which could not be obtained with an anneal.

f. The quality of the silicon electrical steel does not appear to be as high as in the US. It is not clear whether table 14-3 is supposed to give average or maximum losses, but for 0.35 and 0.5-mm thick sheet of the highest silicon grade, the lowest (V_{10}) loss figures are 1.7 watts/kg at 10,000 gausses and 50 cycles. For the same test conditions and thicknesses, Allegheny Ludlum Steel Corporation gives guaranteed maximum losses as low as 0.93 watts/kg for 0.35-mm thickness, and 1.26 for 0.50 mm.

Allegheny Ludlum Electrical Steel Sheets and Coiled Electrical Steel Strip.

g. One of the few unusual grades is EI 454 steel with about 0.2% C, 1.7% Cr, 0.7% Mo, 0.9% Ni and 0.8% Cb, which is said to have given good results "recently" for steam pipes. The properties given appear to be about the same as for a similar steel without nickel and columbium.

h. Although the use of aluminum in place of copper in generators is mentioned, there is no indication that aluminum alloys are considered. In the US, it has been found necessary to go to an aluminum alloy, such as Cond-Al, for large generators operating at high rotational speeds, where unalloyed aluminum was not satisfactory. There is also no mention of carbon or graphite gland seals, which have been and are widely used here in steam-turbine practice. Recently, however, the opinion has been expressed that their record has not been wholly satisfactory and that they will not be suitable for higher operating temperatures.

N. L. Mochel: Wear in Steam Turbines. Mechanical Wear. ASM (1950) pp 145/162; disc 162/164.

i. Apparently sufficient alloy is available for power-plant construction so scarcity and conservation hardly need consideration.

(1) The use of lower tin contents in nonferrous bearing metals is advocated, not because of scarcity but because of cost. Lead-base babbitts containing calcium and alkaline-earth metals are also suggested. According to the 1948 Metals Handbook, the use of the latter type of bearings is confined almost entirely to the railroad field in the US, although they are also employed in certain diesel bearings.

(2) Price is also mentioned as a detriment to the use of Monel Metal.

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(3) The arguments in favor of carbon steel as opposed to a 3% Ni steel (p 450) are sound technically and therefore this does not need to be a reflection of scarcities. Also, if nickel were scarce, there would probably be some mention of the 3% Cr - 0.5% Mo steel used in Great Britain for large turbine and turbine-generator shafts, although such a steel has not been used here. (In Germany it has been used for hydrogenation vessels but not for large shafts and rotors.)

H. H. Burton: Forgeage, Traitment Thermique et Controle Metallurgique d'un Rotor en Acier Allie. Comptes Rendus des Journees de la Grosse Forge (May 1948).

H. H. Burton: Improved Manufacture of Large Alloy Steel Forgings. Metal Progress 63 (1953) no. 1, pp 125/129.

(4) Fewer of the high-temperature steels and of the steels for large forgings contain vanadium than is the case here, or in Germany or Great Britain. Vanadium is supposed to be relatively available in the USSR, so this may be a reflection of lower temperatures.

(5) There is less mention of cobalt-base hard-surfacing alloys than would be expected here.

(6) In the case of nonmagnetic steel, the combination of manganese plus copper is said to be cheaper than the use of 10% Ni. This could hardly be a result of scarcity of nickel, since another nonmagnetic composition given contains about 15% Ni and only 3% Mn; here the proportions of nickel and manganese would probably be reversed.

(7) A note to one of the tables changes the old 0.4/0.6% Mo limit for steam-boiler tubes to 0.4/0.55%, in accordance with the "new GOST 4543". This might be an attempt to save molybdenum by using narrower melting limits.

(8) The use of aluminum instead of copper in generator parts might be due to its lighter weight as well as to its greater availability.

4. Other stresses the importance of rigid inspection and attributes the "few" failures in this field to careful inspection tests. Most of the standard test procedures are used here also. Impact tests, however, appear to be specified more frequently in the USSR than here. Sulfur prints likewise seem to be widely required in the USSR although they are seldom specified here; in view of some of the dirty steels shown in the photomicrographs, this may not be too surprising. A method of determining residual stress by machining a ring from the body of shafts and rotors appears to be standard in the USSR but not here. On the other hand, the use of strain gages, brittle lacquer, and - most important of all - supersonic inspection apparently is unknown. Magnetic-particle tests seem to be used and required much less frequently in the USSR than here.

F. Buckley: Developments in Steel Castings in the Heavy Power Plant Industry. Foundry Trade Journal 94 (1953) pp 405/411; 439/444.

G. T. Jones: Heavy Commercial Forgings. Mechanical Engineering 72 (1950) pp 629/633.

A. W. Rankin, C. J. Boyle, C. D. Moriarty and B. R. Seguin: Thermal Cracks in Turbine and Generator Rotor Forgings. ASME preprint no. 50-S-16 (1950).

R. Schinn and U. Wolff: Einige Ergebnisse der Ueberschallprufung schwerer Schmiedestucke mit dem Impulsecho-Verfahren. Stahl und Eisen 72 (1952) pp 695/701; disc 701/702.

W. Stauffer: Investigation of Materials for Steam Turbine Manufacture. Escher-Wyss News (1950-51) pp 23/24; 91/97.

The specification that the tolerances on steel-casting weights may be ± 15% on castings up to 300 kg, and + 10% - 15% on heavier castings appears unusually high.

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5. Of the [illegible] references (the numbers go to 96, but there is no 27), 75 are in Russian, and 19 are non-Russian. Most of the 19 are German (12). Of the 75 Russian references, Oding himself is author, co-author or editor of 15.

a. The amount of chauvinism and priority claims is quite limited and generally appears in footnotes.

b. The use of foreign trade names and of obviously converted temperatures clearly indicates much of the work is foreign. In some cases, credit is given in the text to foreigners, even when a Russian reference is used. On the other hand, some foreign work is not acknowledged.

(1) Figures 4.27 through 4.33, for example, are all based on US work. The first three of these were taken without credit from The Timken Roller Bearing Co's Digest of Steels for High Temperature Service.

(2) Figure 10-10 is attributed to a Soviet source instead of to the original - C. E. Sims and F. B. Dahle: Effect of Aluminum on the Properties of Medium Carbon Cast Steel. Trans AFA 46 (1938) pp 65/132.

6. There are several interesting innovations in this book.

a. Russian books generally follow the French pattern, with the table of contents in back and no index. Oding has a table of contents in front, and a reasonably comprehensive, [illegible]-page index in back.

b. Unlike most recent Russian books, there is no errata sheet. A number of typographical errors were noted, however.

c. In the preface, Oding gives his address and asks readers to write him about any inadequacies.

d. The numbering system for tables and figures follows that used in recent US textbooks; namely, they are numbered from the start of each chapter and not from the start of the book. For example, figure 4-10 is the tenth figure of chapter 4.

7. Oding's book does have certain basic inadequacies.

a. Many of the figures are photographs and photomicrographs despite the poor reproduction.

b. In some cases, inadequate information is supplied to permit proper use of the data. For example, specific compositions and prior treatments are not given in figure 2-14 and table 4-1. Also, in figure 4-29, the high silicon content of 1.55% has been omitted; this would have a marked effect on elevated temperature properties.

c. The viewpoint is often limited, so many statements could be considered incorrect if the entire field of metallurgy were involved. For example, on page 54, the last paragraph totally ignores the fact that many steels intentionally have high sulphur contents, sometimes as much as 0.3%, for free machining. Also, spheroidization of carbides is of major importance only with carbon and low-alloy steels, but not with high-alloy steels.

d. Oding lets himself be sidetracked into spending far more time with certain topics than would seem warranted. For example, the space devoted to room-temperature fatigue properties and inoculated gray iron appears to be disproportionate in view of their more-or-less limited significance in power-plant technology. Yet he does not seem to treat in sufficient detail some very important subjects, such as bolts; valves; welding procedures; effect of notches on creep and stress-rupture strength; and the expected statistical variation of creep, stress rupture, fatigue strength and other elevated-temperature properties.

e. There appears to be no code, such as the US Boiler Code, to help the designer decide what working stresses are safe. Moreover, there is only a relatively limited amount of accurate creep data and so-called design curves that apply to the steels actually used in the USSR in the condition in which they are normally put into service.

f. Oding's discussion of some topics is quite confused.

(1) He differentiates properly between temper brittleness and the brittleness that may develop in steels on long exposure at temperature under stress; but he becomes confused in his description of the latter and does not properly distinguish between embrittlement of low and high-alloy steels, which are caused by very different phenomena.

(2) His description of graphitization in chapter 8 is reasonably accurate, but in chapter 9 there are a number of incorrect statements. (Incidentally, the Soviets appear to have encountered graphitization, but seem to have had no serious failures. Graphitization has been encountered in the US, and linked with the use of aluminum in melting to get a fine grain size. On the other hand, no such occurrence has been reported from either Great Britain or Germany; and only a single case from France. This would indicate that Soviet melting practices for these steels were presumably similar to those formerly used in the US.)

(3) The discussion of inoculated cast iron is rather fuzzy. Oding seems to consider gray iron and inoculated cast iron as two entirely different types of material; perhaps this is general in the USSR, as they seem to be covered by different specifications. In the US inoculation is simply an accepted aid in the production of most high-strength gray cast iron. Specifications do not distinguish between inoculated and uninoculated iron. Some of the differences Oding attributes to inoculation are probably caused by other variables.

8. Despite the various shortcomings, this book should be useful to engineers and metallurgists having anything to do with steam power plants. It is of course already dated as is natural with any book in a rapidly changing field. I know of no book in English that covers just this specific field, although there are many technical papers on variation of phases of this problem.

-End-